

# METAL TECHNOLOGY OF THE HARAPPA CULTURE

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## 1. INTRODUCTION

For many millennia man struggled with stones to make his tools. The Stone Ages were long periods of stagnation and imperceptibly slow growth. Stone as a material for tools had its obvious limitations, so also wood and bone. The advent of the metal was a real breakthrough in man's technological progress; it was not only tougher and susceptible of a finer edge and more durable but also fusible, malleable and ductile. Worn out tools could be recast and moulds could be improved to obtain any desired shape.

The mastery of the metal was a big boost to the social development. It improved the productivity of the society, led to the development of specialized crafts and provided knowledge of chemical and physical laws. Given the right type of ecology and social set-up, metal technology accelerated the pace of urbanization and led to a host of technical innovations.

Metallurgy had its various stages. In the beginning native copper was used only as 'stone' and was chipped to shape tools.<sup>1</sup> Later, it was hammered and cut to shape. But real metallurgy started with the 'Ore-stage' when man learnt to extract metal from its ores by smelting. This involved complicated processes. All complex processes had their origins at only a few centres which provided the optimum conditions for such discoveries and innovations. Such techniques could not originate independently everywhere, but were diffused from a few primary centres.

The mountain region extending from Anatolia, Armenia to Afghanistan is rich in metal minerals, especially the eastern flank. This zone is the home of wild pistachio and *Haloxylon amodendron*—as shown by recent pollen studies—which pro-

1. Forbes, R. T., *Studies in Ancient Technology*, 9; Leiden, E. J. Brill, 1964.

vide superb charcoal for metallurgical purposes.<sup>2</sup> Recently the importance of Kerman range in south-east Iran has been emphasized in the development of early metallurgy. Discovery of smelting equipment from Tal-i-iblis, in Mashiz Valley, datable to *circa* 4000 B.C., does indicate the probability of its being one of the earliest smelting centres.<sup>3</sup> It is quite likely that for the eastward diffusion of metal technology this site had a crucial role to play. In fact, evidence of contact between Rana Ghundai II and Daruyi near Tal-i-Iblis is reported.<sup>4</sup>

Nearer home, Deh Murasi<sup>5</sup> and Mundigak<sup>6</sup> provide evidence of metallurgy. The volute headed pin, bent blades of lance-head, shaft-holed axe may provide links between Mohenjo-Daro and Mundigak.

Pre-Harappan cultures it appears were not producing their own metal, as it is extremely rare, e.g. only a bangle at Kot Diji I, no metal at Siah Damb and Anjira and only an indeterminate object in Kalibangan I. It may, however, be noted that from Nal, knives, axes, saws, etc., quite a few objects from Mehi and knife blades from Damb Sadaat II and III are reported. In contrast, there is a sudden efflorescence of metal in the Harappa culture. For example, Mackay<sup>7</sup> reported from the further excavations at the DK-mound of Mohenjo-Daro alone, 14 spearheads, 64 knives, 23 axes, 2 swords, 53 chisels, 11 fish-hooks, 2 saws, 18 razors, 17 arrowheads and many other artifacts! This richness in metal has a far-reaching socio-economic importance.

In trying to seek the reasons for the metal prosperity of the Indus people we will be unravelling several other important as-

2. Wertime, T. A., *Science*, 146, No. 3469, p. 1257, 1964.
3. Caldwell, J. R., and Shahmirzadi, S. M., *Tal-i-Iblis: The Kerman range and the beginning of smelting*; Springfield, Illinois State Museum, 1966.
4. Lamberg Karlovsky, G. C., *American Anthropologist*, 69, No. 2, p. 145, 1967.
5. Dupree, L., Deh Morasi Ghundai: A Chalcolithic Site in South-Central Afghanistan; *Archaeological Papers of the Museum of Natural History*, 50, pt. 2, New York, 1963.
6. Casal, J. M., Fouilles de Mundigak: *Memoires de la Delegation Archeologique Francaise en Afghanistan*, 17, Paris, 1961.
7. Mackay, E. J. H., *Further excavations at Mohenjodaro*; New Delhi, Government of India Press. 1937-38.

pects of the Harappa culture too. Because metallurgy provides the technological base—the means of production—of a given society, the change in the means of production does determine to a considerable extent the superstructure. In the case of the Harappan urbanization also, metallurgy has played a crucial role.

## 2. THE PROBLEMS

To define the technological status of the Harappa culture in the fields of metallurgy and metal forging as also to understand its socio-economic implications, we will tackle the following problems :

- (i) Did the Harappans use smelted copper?
- (ii) What types of mineral ores were used?
- (iii) Can we locate the sources of these ores?
- (iv) Did they practise deliberate alloying?
- (v) What metal-forging techniques they used?
- (vi) Does typological analyses show affinity of the Harappans with the Copper Hoards or with the other Chalcolithic cultures?
- (vii) What is the role of metal technology and the ecology in the urbanization of the Harappa culture?

These are big problems and let it be admitted that there are no easy answers. But the chemical and metallographic analyses of our samples, as also previous work of other workers, do throw important light on the state of metallurgy in the Indus. In the light of chemical, metallographic, typological, as also ecological data we can now make an attempt to seek answers\* for the problems posed above.

## 3. CHEMICAL ANALYSES

Before we spell out our approach it will be relevant to review the previous work. Desch started the pioneering work in this field under the aegis of the Sumerian Committee. He was in a way obsessed with nickel and went to the extent of seeking Transvaal copper ores (which contain nickel) as the

\* The conclusions drawn here can only be tentative in the present stage of knowledge. But more analyses and data are being processed which would lead to firmer conclusions.

sources for Mesopotamian copper! Sanahullah<sup>8</sup> sought to distinguish the Harappan artifacts from the Mesopotamian ones on the basis of absence of arsenic in the latter. But Table I will show that arsenic and nickel both were present in west Asian artifacts and therefore arsenic is in no way distinctive of the Indus.

TABLE I

Sites		Total number of tools	With Ni	With As
Egypt	..	30	8	22
Khafaje	..	16	14	13
Ur	..	16	15	14
Kish	..	10	10	1

(Based on the data given by Burton Brown<sup>9</sup>)

Problems of ore-correlations are quite controversial and complicated. In the West, Coghlan, Oldberg, Pittioni, Junghans and Sangmeister have done important work in this line, though Thomson<sup>10</sup> has challenged the very fundamentals of their work. However, Coghlan<sup>11</sup> has defended Pittioni and others' approach of comparing the impurity patterns of the ores and the artifacts for ore-correlations. Even Thomson<sup>12</sup> admits that the use of pyritic ores can be discerned from the increase of impurities (Table II) like tin, arsenic, iron and nickel. We observe an increase in these impurities in Mohenjo-Daro samples too (Tables III and IV), indicating the use of sulphide ores. Presence of sulphur too was frequently detected.

8. Sanahullah, In Vats, M., *Excavations at Harappa*, New Delhi, Government of India, 1940.
9. Brown, Burton T., *Excavation at Azarbaijan*; London, Murray, 1951.
10. Thomson, F. C., *Man*, 58, p. 1, 1958.
11. Coghlan, H. H., *Viking Fund Publications in Anthropology*, 28, 1960.
12. Thomson, F. C., *op. cit.*

TABLE II

[The use of pyrite ores from the late third millennium B.C. With the use of sulphide ores the impurities record a sharp increase (after Thomson 1933)]. n.d. = not detected spectrographically. Figures for copper in brackets are by difference.

## Percentage composition

	Copper	Tin	Iron	Nickel	Lead	Arsenic	Zinc	Bismuth	Antimony	Silver
Native copper .. ..	(99.96)	0.0005	0.0002	0.03	n.d.	n.d.	n.d.	n.d.	n.d.	0.0025
Early third millennium (male-chite ?) .. ..	(98.43)	0.02	0.3	0.005	0.002	0.1	0.005	0.0005	0.03	0.1
Middle third millennium (male-chite ?) .. ..	(98.7)	0.03	—	0.002	0.01	0.2	0.005	0.002	0.03	0.01
Later third millennium (weathered pyrite ore ?) .. ..	(98.98)	0.5	0.1	0.03	0.05	0.3	—	0.0008	0.06	0.01
Later third millennium (pyrite ore ?) .. ..	(97.41)	0.87	0.02	0.16	0.56	0.20	—	—	—	—

TABLE III  
Percentage composition

Site: Mohenjo-Daro, from lower levels

Sample details	Ag	Fe	As	Sb	Pb	Bi	Cu	Sn	Ni	S	Rel. prob. %			Reference
											I	II	III	
Pl. CXXVI, 5 DK 7535	—	0.33	0.66	0.25	0.59	—	91.01	6.14	0.48	0.12	0	18	82	(Mackay 1937-38)
Pl. CXXVII, 2 DK 7854 Axe	—	0.50	—	0.43	0.95	—	90.98	7.66	0.20	0.07	0	40	60	"
Pl. CXXVI, 2 DK 7856 Chisel	—	0.51	—	1.25	0.39	—	75.23	7.84	0.61	—	0	23	77	"
Portion of Axe DK 7861	—	0.10	—	0.14	0.22	—	88.49	9.88	0.30	0.06	0	44	56	"
Pl. CXXVIII, 1 DK 5488 Axe	—	0.34	2.10	Tr	0.20	—	80.56	1.76	0.58	—	1.0	54	45	"
Pl. CXXXIII, 4 DK 6043 Chisel	—	0.02	1.58	0.54	Tr	—	86.92	8.56	0.68	0.07	5.0	15	80	"
Pl. CXXVIII, 15 DK 6360 Copper frying-pan	—	0.33	0.80	0.18	0.05	—	81.94	0.37	0.21	0.14	0	38	62	"
Pl. CXXVII, 14 DK 7848 Bolt	—	0.29	0.24	—	0.81	—	97.23	—	0.89	0.10	0	69	31	"
Pl. CXXVI, 4 DK 7853 Axe	—	0.38	0.40	0.06	0.71	—	94.64	0.21	0.33	0.69	0	6	94	"
Pl. CXXIX, 22 DK 7859 Ingot		0.56	0.24	—	0.82	—	95.23	—	0.41	0.48	1	83	16	"

TABLE IV  
Percentage composition

Site: Mohanjo-Daro

Sample details	Ag	Fe	As	Sb	Pb	Bi	Cu	Sn	Ni	S	O <sub>2</sub>	Rel. prob. %			Reference
												I	II	III	
Copper lump	—	0.03	0.15	0.88	0.02	—	96.67	—	1.27	0.98	—	0	19	81	(Marshall 1931)
" "	—	0.49	—	0.98	Tr	—	97.07	—	0.81	1.15	—	5	31	64	"
" "	—	—	—	—	0.09	—	96.42	—	0.85	0.86	2.78	1	98	1	"
" "	—	1.51	1.80	Tr	Tr	—	92.49	0.37	1.06	Tr	1.01	4	53	43	"
Fragments of implements	—	0.12	0.74	0.72	1.58	—	95.80	—	0.25	0.61	0.18	0	6	94	"
Celt	—	0.15	4.42	—	0.26	—	94.76	0.09	0.14	—	—	0	3	97	"
Copper chisel	—	0.59	3.42	0.10	3.28	—	92.41	—	0.15	0.05	—	0	18	82	"
Bronze rod	—	0.15	1.96	1.15	0.17	—	91.90	4.51	—	0.16	—	0	1	99	"
Bronze buttons	—	0.29	Tr	2.60	—	—	88.05	8.22	Tr	0.84	—	5	11	84	"
Bronze chisel	—	0.35	—	0.35	0.70	—	86.22	12.38	—	—	—	0	34	66	"
Bronze slab	—	0.42	1.17	0.33	0.11	—	82.71	13.21	0.56	—	1.49	0	5	95	"
Bronze chisel	—	0.18	0.07	Tr	Tr	—	85.37	11.09	0.16	0.11	3.02	6	61	33	"
Bronze lump	—	—	—	Tr	0.17	—	83.92	12.13	0.17	—	3.61	5	84	11	"

TABLE V  
Percentage composition

Site : Rangpur

Sample details	Period	Ag	Fe	As	Sb	Pb	Bi	Cu	Sn	Ni	O <sub>2</sub>	Rel. prob. %			Reference
												I	II	III	
1. No. 324 Celt	IIC	—	—	—	—	Tr	—	91.2	2.6	2.1	4.1	47	51	2	(Rao 1963)
2. No. 663 Celt	IIa	—	—	Tr	—	Tr	—	91.35	4.09	Tr	4.6	"	"	"	"
3. No. 437 Bangle	IIC	—	—	Tr	—	Tr	—	86.4	11.07	1.8	0.73	"	"	"	"
4. No. 417 Knife	IIC	—	Tr	—	—	—	—	94.8	0.7	0.4	4.1	"	"	"	"
5. No. 330 Pin	III	—	1.88	—	—	—	—	91.8	0.6	5.88	—	8	84	8	"
6. No. 442 Pin	IIB	—	1.86	—	—	—	—	96.6	Tr	0.8	0.74	"	"	"	"
7. No. 360 Bead	IIa	—	1.4	—	—	—	—	96.66	Tr	0.38	1.56	"	"	"	"
8. No. 635 Ring	IIa	—	0.45	—	—	—	—	96.1	Tr	0.2	3.25	52	25	23	"
9. No. 169 Bangle	?	—	Tr	—	—	—	—	57.7	6.94	Tr	35.46	47	51	2	"
10. No. 170 Amulet	IIa	—	0.57	—	—	—	—	77.6	Tr	0.1	21.73	52	25	23	"
11. No. 141 Pin	IIa	—	0.24	—	—	—	—	65.4	6.78	0.51	27.08	26	56	18	"
12. No. 526 Knife	IIC	—	Tr	—	—	—	—	59.0	5.28	Tr	35.72	47	51	2	"
13. No. 525 Knife	?	—	1.08	—	—	—	—	59.6	2.69	—	36.63	8	84	8	"



TABLE VI  
*Comparison of the impurity patterns of the copper artifacts from Ahar and the Khetri copper ore*  
*Spectroscopic analyses*

Sample description	Ag	Fe	As	Sb	Pb	Bi	Cu	Sn	Ni	Zn	Mn	Co	Au	Al	Cr	Mo	Zr	W	Tl	Mg	V	Gd	P	Si	Reference	
Ahar axe	..	nd	+	+	+	+	+	nd	+	+	+	+	nd	+	+	+	+	nd	+	+	nd	+	+	+	+	(Hegde <i>in press</i> )
Ahar metal sheet	..	nd	+	+	+	+	+	nd	+	+	+	+	nd	+	+	+	+	nd	+	+	nd	+	+	+	+	"
Khetri ore	..	nd	+	+	+	+	+	nd	+	+	+	+	nd	+	+	+	+	+	+	+	+	+	+	+	+	"

Key: + = present  
 nd = not detected

We have, however, used the statistical approach of Friedman *et al.*<sup>13</sup> to determine the types of ores used. They analysed a large number of ore and artifact samples and arrived at the relative probabilities of occurrence of impurities in the three types of ores : native, oxides and sulphides.

Subjecting the more complete of the chemical data available for Mohenjo-Daro artifacts to statistical calculations (as per Friedman *et al.*) we arrived at the relative probabilities for the type of ores used as given in Tables III and IV. In the tables, relative probability I is for the native type, II for the oxidized type and III for the reduced type of ores. It is clear from Tables III and IV that there is a very high probability that sulphide ores were used by the Harappans from the beginning. On the other hand, at Rangpur fresh mining areas may have been tapped, as it appears that they used either native or oxidized copper minerals (Table V).

But once we go into the ore-correlations to determine definite mining areas which the Harappans used, the problem becomes more complicated. To get a definite answer to these problems many more analyses are needed; but let us see as to what inferences are possible on the basis of the available data.

Table VIII shows our spectroscopic analyses of the various Indian ores and two Harappan artifacts (TF-Cu-3 and -6). It is evident from the table that only the Khetri ore has close correspondence with the impurity patterns of the Harappan artifacts. Hegde<sup>14</sup> too, following Pittioni, has compared the impurity patterns of the Khetri ore and the Ahar artifacts, and there is a surprising correspondence between the two (Table VI). Besides the common presence of several impurities in the Khetri ores and the Ahar tools, the absence of silver, gold and tin even in trace amounts is remarkable.

13. Friedman, A. M., Conway, M., Kastner, M., Milsted, J., Metta, D., Fields, P. R., and Olsen, E., *Science*, 152, No. 3728, p. 1504, 1966.

14. Hegde, K. T. M. (*in press*).

TABLE VIII  
*Spectroscopic analyses\**

## Indian ores and artifacts

Sample description	Ag	Fe	As	Sb	Pb	Bi	Cu	Sn	Ni	Zn	Mn	Co	Al	Cr	Mo	Zr	W	Th	Mg	V	Gd	P	Bi
<b>TF-Cu-14a</b> Madras pyrrhotite	nd	+	nd	nd	nd	+	nd	+	+	nd	+	nd	nd	nd	nd	nd	+	nd	nd	nd	nd	nd	nd
<b>TF-Cu-14b</b> Madras pyrrhotite	nd	+	nd	nd	nd	nd	+	nd	+	+	nd	+	nd	nd	nd	nd	+	nd	nd	+	nd	nd	nd
<b>TF-Cu-5</b> Mohenjo-Daro galena ore	nd	nd	nd	+	+	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
<b>TF-Cu-15</b> Singhbhum chalcopyrite	nd	+	nd	nd	nd	nd	+	nd	+	+	+	+	nd	+	nd	+	nd	nd	+	+	+	nd	+
<b>TF-Cu-2a</b> Khetri chalcopyrite	+	+	+	+	+	+	+	+	+	+	+	+	nd	+	+	nd	nd	+	+	+	+	nd	+
<b>TF-Cu-3</b> Chanudaro celt	+	+	+	+	+	+	+	+	+	+	+	+	nd	+	+	nd	nd	+	+	+	+	nd	nd
<b>TF-Cu-6</b> Mohenjo-Daro spearhead	+	+	+	+	+	+	+	+	+	+	+	+	nd	+	+	nd	nd	+	+	+	+	nd	nd

\* My samples

Key: + = present

nd = not detected

ns = not looked for

TABLE VII

Range	Elements
More than 1%	Si, Fe, Cu
0.1-1.0%	Al, Mg and Ni
0.001-0.1%	Zn, Mn, Co, Mo, Ti and V
Not detected	Sn, Pb, As, Au, Ag, Bi, Cr, Gd and Sb

As compared to Khetri ore, we got the following spectroscopic analyses for a chalcopyrite sample from Singhbhum :

The absence of Pb, As, Bi, Cr, Gd in the Singhbhum ore distinguishes it from the Khetri ore. But most of these elements are present, quite often in significant amounts, in the Harappan copper (Tables III, IV and V). This evidence suggests that the use of Rajasthan ores by the Harappans is more probable than the Bihar ores.

#### 4. ALLOYING

Brown<sup>15</sup> has adduced evidence to show that tin alloying was known in the third millennium B.C. Childe<sup>16</sup> held that in Mesopotamia lead alloying for better moulding of copper was learnt by late Uruk times, whereas tin alloying appears in Early Dynastic times at the latest.

But in the Indus there is evidence for tin alloying right from the early levels (Table III), though in point of time later than West Asia. Of course, small amounts of Sn, Sb, Pb, Ni and Fe came from the ores only, as impurities, and were not deliberate additions. Tin-bronzes, with 8-11% tin, are the best for an optimum combination of strength, elasticity, toughness and the ability to stand shocks. More than 11% tin in bronze makes it brittle, yet is good for imparting it a bright polish.

Below we give the percentage of tools, out of 175 published chemical analyses studied by us, in different concentration-ranges of tin :

15. Brown, Burton T., *op. cit.*

16. Childe, V. G., *New light on the most Ancient East*, New York, Grove Press Inc., 1957.

Sn%	..	<1%	<8%	8-12%	>12%
Tool%	..	70%	10%	14%	6%

From the above, two points emerge : (1) most of the tools (70%) are of pure copper and (2) out of the bronzes only 14% fall within the optimum tin concentration of 8-12%. This indicates both scarcity of tin as also the inability of the Harappans to control the optimum range either due to the lack of knowledge or difficulties of correct mixing.

Data on arsenic alloying are not clear, as arsenic was not always looked for in the older analyses. But about 20 artifacts (out of the 175 mentioned above) show 1-6% concentration of arsenic which could only be due to deliberate addition. Up to 4% arsenic in copper forms a solid solution, but increases the strength of the alloy in the cast condition only marginally.<sup>17</sup> However, it acts as a deoxidizer and is useful in closed-casting.

On the other hand, up to 8% tin forms a solid solution with copper and in annealed condition up to 16%. A 10% tin bronze will have a Brinell hardness of 135, as against 87 of pure copper, while retaining its ductility. Cold work on pure copper too can harden it comparatively, but will make it very brittle. Work-hardened bronze can achieve considerable hardness.

### METAL FORGING TECHNIQUES

Most of the Harappan tools are of a simple type; the sophistication of West Asia is absent here. Even such a utile device as a shaft-hole too was not adopted. All the Harappan axes are of a flat type only. Even the blades of knives and spearheads (with the exception of four mid-ribbed swords from Mohenjo-Daro)<sup>18</sup> are of a thin flat type. Amongst the distinctive Harappan types we may include the razors (especially the double-edged one), the blades with curved ends, chisels with broad rectangular tangs and narrow blades, barbed fish hooks, arrowheads with backward projecting bars. Fish hooks of course are pieces of superb craftsmanship and are unparalleled in any other Chalcolithic culture in India,

17. Tylecote, R. F., *Metallurgy in Archaeology*, London, Edwin Arnold, 1962.

18. Mackay, E. J. H., *op. cit.* 1937-38.

even in Mesopotamia and Egypt.<sup>19</sup> The cute figurines of the nude dancing girls from Mohenjo-Daro<sup>20, 21</sup> and Lothal are masterpieces of the Harappan bronze sculpture.

The dancing figurines mentioned above are not only fine sculptures, but are also the evidence of *cire-perdue* casting techniques used. Closed casting was a known art to the Harappans. Addition of small amounts of lead to enhance the fusibility of copper and of arsenic as deoxidizer may have been deliberate attempts for efficient casting. However, several specimens of axes<sup>22, 23</sup> with puckered surface and large blow-holes do indicate difficulties of casting. The large number of flat celts and other flat type of implements indicate a probable predilection for the easy open mould casting. Metallographic analyses indicate that cooling of the cast metal was slow and controlled.

Pots and pans were made using 'sinking' and 'raising' techniques. In some cases one can observe even the stake marks on the inside of vessels.<sup>24</sup> No wire drawing is attested, though wires were made by beating. Objects with thin sections, for example razors, arrowheads, even knife blades, were made by chiselling out from copper sheets.

Worthy of mention is the occurrence of a true saw from Mohenjo-Daro with unidirectional indentations;<sup>25</sup> elsewhere it does not appear till the Roman times. The fine tubular drills<sup>26</sup> too are the earliest metal drills in the world.<sup>27</sup> They were probably made by beating over a mandrel. Mackay<sup>28</sup> suggested that they were perhaps used for making fine steatite beads.

19. Hora, S. L., *Ancient India*, 10 and 11, p. 152, 1954-55.

20. Marshall, J., *Mohenjodaro and the Indus Civilization*, Pl. XCIV, 6-8, Arthur Probsthain, 1931.

21. Mackay, E. J. H., *op. cit.*, 1937-38.

22. Mackay, *Chanhudaro excavations*, Pl. CXX, 27, New Haven, American Oriental Society, 1943.

23. Mackay, *op. cit.*, Pl. CXXXII, 36, 40, 1937-38.

24. Mackay, *op. cit.*, 1937-38.

25. Mackay, *op. cit.*, 1937-38.

26. Mackay, *op. cit.*, Pl. LXII, 1943.

27. Coghlan, H. H., In Singer, C., Holmyard, E. J., and Hall, A. R., *A History of Technology*, 1, Oxford, Clarendon Press, 1954.

28. Mackay, E. J. H., *op. cit.*, 1937-38.

Though soldering for gold was known to the Harappans, it appears that it was never used for copper. For metal joining the 'running on' and riveting techniques were used.<sup>29</sup> Lapping of tubular handles was also known.<sup>30</sup>

To determine if the Harappans knew the techniques of cold working and annealing, six samples were analysed from Chanhudaro and Mohenjo-Daro. The metallographic analyses showed polygonal grains with twins indicating cold work and annealing. Lack of cracking and large pores in the case of a Mohenjo-Daro bowl (TF-Cu-7) may indicate slow cooling of the mould.

### ECOLOGY AND TECHNOLOGY

We have tried to sketch above an outline of the Harappan metallurgical technology. A 2,000-year late date<sup>31</sup> for Harappan metallurgy than Iran and the evidence of a full-blown metallurgy from the start itself preclude any probability of independent origins in the Indus. Harappans were smelting quite pure copper from the sulphide ores and practised tin and arsenic alloying also. It is probable that they were using ores from Khetri area. They were relatively rich in copper and had learnt various techniques of metal forging. They knew 'sinking', 'raising', cold work, annealing, 'running on', riveting *cire-perdue* casting. They even had the earliest tubular metal drills and the true saw. We also noted the distinctive tool-types of the Harappa culture.

In comparison to the Harappans the other Chalcolithic cultures are poorer both in the quantity of the metal and the technology. The Copper Hoards are also rich in the metal, but they are comprised of unstratified collections from far-flung sites. Some of them may not belong to the same culture even. However, they have their own distinctive tool-types—the harpoon, the anthropomorph and the antennae sword—which are completely unrelated to the Harappans. The tool-repertoire

29. Mackay, In Marshall, J., *Mohenjodaro and the Indus Civilization*, London, Arthur Probsthain, 1931.

30. Mackay, *op. cit.*, Pl. CXXII.

31. Agrawal, D. P., *Science*, 143, No. 3609, p. 950, 1964.

of the Copper Hoards was specially adapted for a hunting-nomadic life in the thick primeval forests of the Doab.

The question arises, when the other protohistoric cultures too had the copper-metallurgy, why was it that only the Harappans ushered into urbanization. This brings in ecological factors.<sup>32</sup>

Ecology is the human habitat which is comprised of the animate and inanimate environment. Ecology provides the opportunities as also imposes limits on human societies. Let us try to reconstruct the ecology of the Harappan times and then study its influence on the society.

It was thought that the Indus area had greater rainfall in the past, had thick forests and swamps with fauna representative of hot and humid climate.<sup>33</sup> Fairservis<sup>34</sup> effectively countered these arguments and showed that the phenomenon of the Harappa Culture was more probable in a dry milieu. Since then Raikes<sup>35, 36, 37</sup> has proved that the climate was dry in that area, as it is today. Panjab and Sind fall in the rain contours of 10" to 20"; in the lower Sind it is less than even 5", as against 25"—40" of annual rainfall in the Doab. The Indus has soft and pliable alluvial plains and a gallery forest. In contrast, the Doab was a thick monsoonal forest<sup>38, 39</sup>. The modern alluvial plains in this region are due to man-made deforestation.

The decline of Mohenjo-Daro has now been shown to have been due to the impounding of the Indus by tectonically caused mud-eruptions—at least four times during the life of the city.<sup>40</sup> But here we do not want to go into the causes

32. Agrawal, D. P., *Bull. Arch. Soc. India*, 1, p. 17, 1967-68.

33. Wheeler, R. E. M., *Early India and Pakistan*, London, Thames and Hudson, 1959.

34. Fairservis, W. A. (Jr.), *American Museum Novitates*, No. 2055, 1961.

35. Raikes, R. L., *American Anthropologist*, 66, p. 284, 1964.

36. Raikes, R. L., *Antiquity*, 39, p. 196, 1965.

37. Raikes, R. L., *Antiquity*, 41, No. 164, p. 309, 1967.

38. Calder, C. C., *In an Outline of Field Science in India*, edited by S. L. Hora, Calcutta, Indian Sci. Cong., 1937.

39. Stebbing, E. P., *The Forests of India*, Vol. 1, London, The Bodley Head, 1922.

40. Raikes, R. L., *op. cit.*, 1965.



and the controversies about the end of the Harappans. We are concerned here more about the origins of their urbanization.

One queer thing about the Harappans is that they impinge as a mature culture on the pre-Harappan cultures—the developmental stages are missing. The individuality of the Harappa culture goes against a foreign origin too. Was it, then, an 'explosive evolution'?

For the urbanization of a society the first requirement is the agricultural surplus. The Indus plains, with annually renewed fertile alluvium, could provide this surplus with little effort. The soil was so pliable that even wood and copper hoes were sufficient for cultivation. The surplus so produced brought the Indus society on the threshold of urbanization—because now the metal technicians could be provided for by the society. Childe said, 'The use of metal tools does not depend upon simply on technical knowledge. A community can only use metal tools when it is producing an effective social surplus.' Metallurgy was a specialized craft and full-time specialists could be used only if a society had concentration and fluidity of the social surplus. Metallurgical know-how and a social-surplus could bring them to the threshold of urbanization. But why this metal efflorescence and full-blown urbanization appearing so suddenly?

It appears that the ecology (in the shape of vast alluvial pliable plains and a gallery forest) provided endless opportunities for increasing the production. What was needed was the tools for agriculture, transport and many other industries of an urbanized centre. Discovery of new mines (was it the Khetri belt?) may have led to sudden progress of the society. Technology, ecology and the abundance of the metal accelerated the pace of development. It may be suggested that the monopolists—discoverers of the mines—may have given the lead to the society and constituted the ruling elite of the Indus civilization. Sudden progress in technology, trade and agriculture could have led to the need of planned cities. If they are pre-planned cities, it is no use looking for their nebulous origins there!

In contrast, the Doab was a thick monsoonal forest. Its clearance needed the strength and the considerable abundance of iron. Limited clearance for agricultural patches was pos-

sible with copper. It was an ecology rich in the jungle game and river fish. The main tools of the Copper Hoards—the harpoon, the anthropomorph\* and the antennae sword—are admirably suited for a hunting-nomadic life. So the ecology imposed severe limitations for any large-scale agriculture. There could be no great surplus and no urbanization till the advent of the Iron Age. The tools were probably made by the itinerant smiths who were at least economically released from the kinship bonds of their tribes.

Similarly, the ecology placed restrictions on the Chalcolithic cultures of Central India too. Agriculture on the sticky cotton soil without heavy iron ploughshares and coulters was not possible. With their meagre copper tools they could only cultivate the thin alluvial strips and thus could never produce sufficient agricultural surplus to come out of the village status.

Thus we see that a developed metallurgy, rich sources of copper, optimum ecological conditions and an efficient village society which could produce fluid social surplus—all contributed significantly to the first Harappan urbanization that India witnessed.

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\* It was a definite missile and not a ritualistic human figure, as is shown by the sharp arms and the heavy blunted head.